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ESL Technical Memorandum No. 15
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30 March 1953

Subject: Analysis of mine-drop signatures for rise-time, amplitude, and frequency characteristics: results of

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Subject: Analysis of mine-drop signatures for rise-time, amplitude, and frequency characteristics; results of

Reference (a) makes the point that information as to the character of mine-drop signatures is needed in order to design functional passive mine-watching systems. The purpose of this memorandum is to indicate results obtained from an analysis of magnetic tape recordings of two types of air-dropped mines, the Mk 36 (from variable angle launcher) and the Mk 39 (high-altitude, air-dropped), taken at Morris Dam (see Ref. b), and during Operation MUD, respectively.

It was previously reported that an air-dropped Mk-39 mine gives a distinct double-peaked signal, while an air-dropped Mk 36 yields only one peak, those signals being the mine-drop signatures and not their reflections. This description is accurate only for an unfiltered signal. Upon filtering, one discovers that in the 100-200 cps frequency range both mine drops have a double peak. There is a difference, however, in the time separation between peaks for the two models. The peaks in the Mk-36 signature are only 0.1 second (average figure) apart, an interval approximately one-third as long as the peak separation time for a Mk 39. This variance in filtered signals may possibly explain the difference found in the audible resolution of the two mines. Furthermore, this double-peak behavior seems to be present only in this low-frequency range, with the most favorable range for optimum peak height and separation resolution around this 100-200 cps range. It has been found that the unfiltered signatures of Mk-36 mines reach their peak amplitude of about 132 db re .0002 dynes/cm^2 in a time of about 20 millisec. This is by no means a monotonic rise, but one punctuated by sharp fluctuations, as illustrated in the photographs of Figure 1. The decible notation refers to db above the voltage produced by a pressure of .0002 dynes/cm^2 at the hydrophone. No quantitative information is available concerning the peak amplitude of Mk-39 mines; however, the time necessary to rise to this unfiltered peak amplitude has been measured as about 80 millisec.

In the case of the 100-200 cps filter range, the first peak of the Mk-36 mine rises to about 123 db in 15 millisec with the second peak rising to about 120 db in nearly 25 millisec. On the other hand, the characteristically longer-lived Mk-39 model rises to its first peak in about 140 millisec, while its second peak rises to a slightly higher level in about the same time.

The method of rise-time and filter band measurement was essentially photographic. Photographs were made using a Fairchild-Polaroid Land camera to photograph the oscilloscope face of a Tektronix Type 512 oscilloscope. In cases where filtering was done, the filter used was a Spencer-Kennedy variable electronic filter, Model 302. Mine drop signals were played from tapes over a Magnecorder PT 6 J whose frequency response had an estimated useful range of 15 to 20,000 cps. The oscilloscope was triggered by means of a metallic foil placed on the tape, effectively closing a switch which completed the trigger circuit. (See Figure 2.) Then a calibration voltage, generated by the oscilloscope, was photographed on each exposure with the mine drop. This calibration voltage gives in each case a standard for easy comparison of the mine-drop pictures. Standard frequencies were also photographed on some of the pictures to establish the sweep rate of the scope.

At the time of mine-drop recording, calibration tones of a specified power level were also placed on the tape. Photographs were made of these standard calibration signals using the same electronic arrangement as in the photographing of the mine drops. This method enabled us to establish a decibel scale on the photographs. The method of rise-time measurement was then essentially graphic, utilizing the decibel scale established by the calibration tones and the known time scale of the scope sweep.

During the testing for a suitable filtering range, an attempt was made to enhance the signal-to-noise ratio and to produce a more characteristic signature by means of R-C "differentiation" and "integration." Neither of these techniques (with or without rectification) seemed to improve results. In many cases the S/N ratio was made poorer by use of either integration or differentiation.

The immediate need arises, however, to know the characteristics of background noise present in a given harbor, since the performance desired from a passive listening network is <u>recognition</u>

as well as location of mine drops. The report on Boston Harbor, Ref (c), would indicate that a maximum of harbor background noise, including ship noise, occurs in the 100 cps region.

An informal study (unpublished) was undertaken by this laboratory of a tape recording of hydrophone noise picked up in New London Harbor. A similar peaking, around 400 cps, is indicated. Thus we find, not-unexpectedly, that the maximum sound energy of harbor background noise tends to be in the low frequencies.

This situation is not as bad as it might appear, since a similar analysis shows that mine-drop noise energy also seems to be maximum in the low energy region. Indeed, a signal-to-noise ratio study on Project MUD drops (where presumably there would be a background of the expected nature, but admittedly not of harbor intensity) indicate that the maximum S/N value is in this very 100-200 cps range (Graph I). This relationship, and the determination of a characteristic mine-drop signature, would be hopeful circumstances for further study of the location-recognition problem.

The possibility that the double-peak nature is unique to drops (as opposed to explosions, machine gun fire, etc.) remains to be demonstrated conclusively. In full scale experiments, this peaking or periodicity could conceivably represent either oscillations of the cavity, the size of which is unknown in full scale experiments, or shock-excited oscillations of the mine case.

These possibilities seem to indicate that further model studies might be useful. The model studies discussed in Ref (d) seem to indicate that pulses subsequent to the first result from mine oscillations being transmitted to the water upon mine cavity contact. If this is the case, clearly the frequency spectra of the second pulse for various mine types should show some relationship to a study of the natural frequencies of mines. Underwater explosions, as indicated by R. H. Cole, Ref (e), indicate that multiple pulses due to cavity oscillations can occur. Since all of these shots (Cole's) were large, deep-water explosions, however, it is clear that the cavity should be important in the determination of their signals, but not decisive in determining the character of small ($<$ 10 lb), shallow explosions, which would approximate a mine-drop and might feasibly be scattered from a plane to mask laying operations. A study made by Project MICHAEL, Ref (f), on explosive noise transmission is not conclusive in this case either, since their transmission distances are such as to make dispersion phenomena possible. If the second pulse is due to cavity oscillation, then presumably there will be some correlation between the nature of the second peak and the nature of the first for the various types of mine drops.

Our studies tend to favor the mine vibration hypothesis, since we get distinctly different characteristics for the second peaks in the two drop types (examples in Graph II). The situation is far from definite, however, since the two types of mines possess distinctly different laying energies, the Mk 36 being parachute dropped.

The data obtained by the tests described would appear to be in distinct conflict with that indicated in H.M.U.D.E. (Great Britain) report, Ref (g), where a double pulse is obtained for low energy drops (300' dropping height) and only a single peak for higher drops (1000' and 1500'). We have consistently received a double peak from the Mk 39 (high energy). Furthermore, the double-pulsed character of our drops has somewhat disappeared at the frequency ranges used by H.M.U.D.E. (3.5 - 15.5 KCS). The possibility exists that their low energy, double pulses are a result of the low entry angle (30°) and subsequent motion of the mine in the cavity. Except for this explanation it is difficult to reconcile this discrepancy.

Certainly the need for further data and analysis is clear. The importance of determining a signature characteristic for the entry of a mine into the water can hardly be sufficiently emphasized. At present it would appear that, both from the aspects of maximum S/N value <u>and</u> of characteristic signature, the low-frequency range 100-200 cps deserves close attention. It was in view of the importance of these facts and the apparent non-universality of this opinion that this memo was prepared.

In order to discover the exact nature of mine signature sound pulses, the following studies should be initiated:

a) An analysis of the spectra of mine drop signatures to determine if the pulses are a function of mine vibration or laying energy, and noting the cross-correlation of these two factors.

b) Vibration studies of the mines themselves, for frequency and excitation energy.

c) An analysis of small (about 10 lbs) shallow water explosion signatures.

d) Rise-times and peak amplitude values for Mk 39 and Mk 25 mines, i.e., accumulation of information similar to that present in the second paragraph of this memorandum.

Problems 9(a) and 9(d) are currently under study at Yale University, by scientists under Contract Nonr-609(02). To this end, work has begun on the design and construction of a hydrophone array and monitoring system to be established at Beavertail Laboratory, Jamestown, Rhode Island, in the summer of 1953. When this installation is completed, it will then be possible to complete studies (a) and (d).

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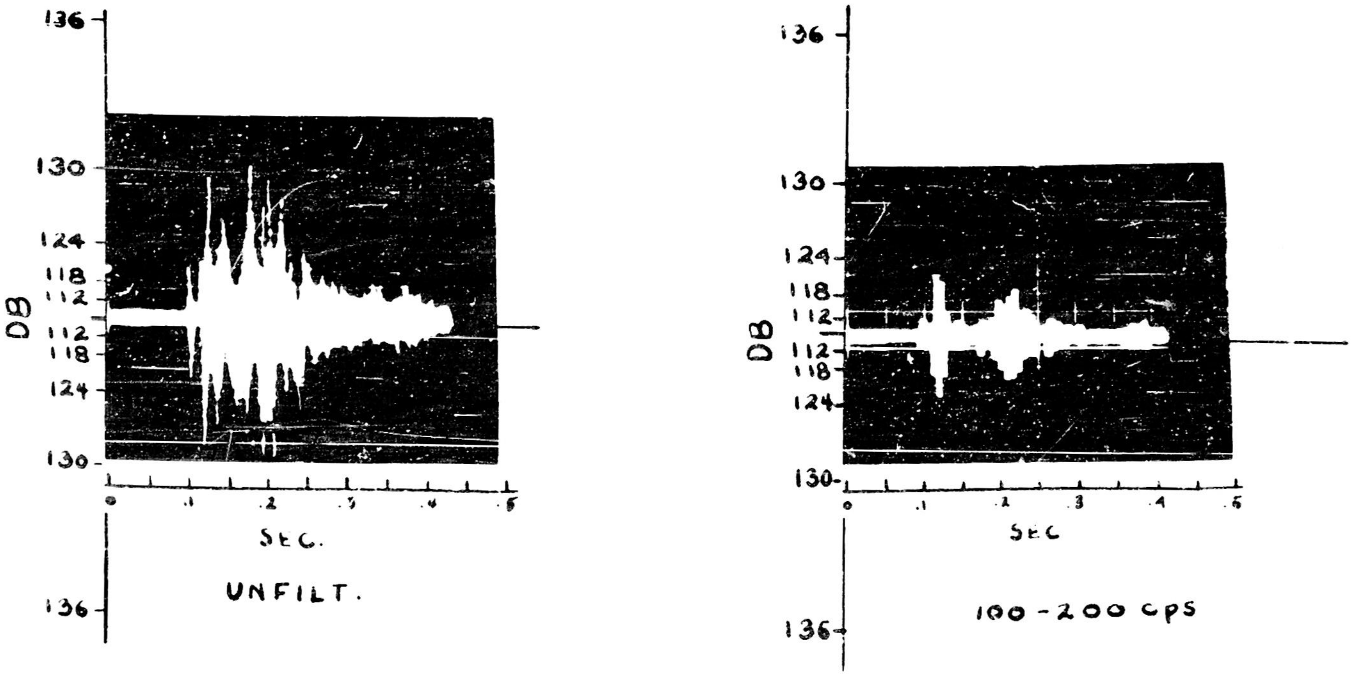
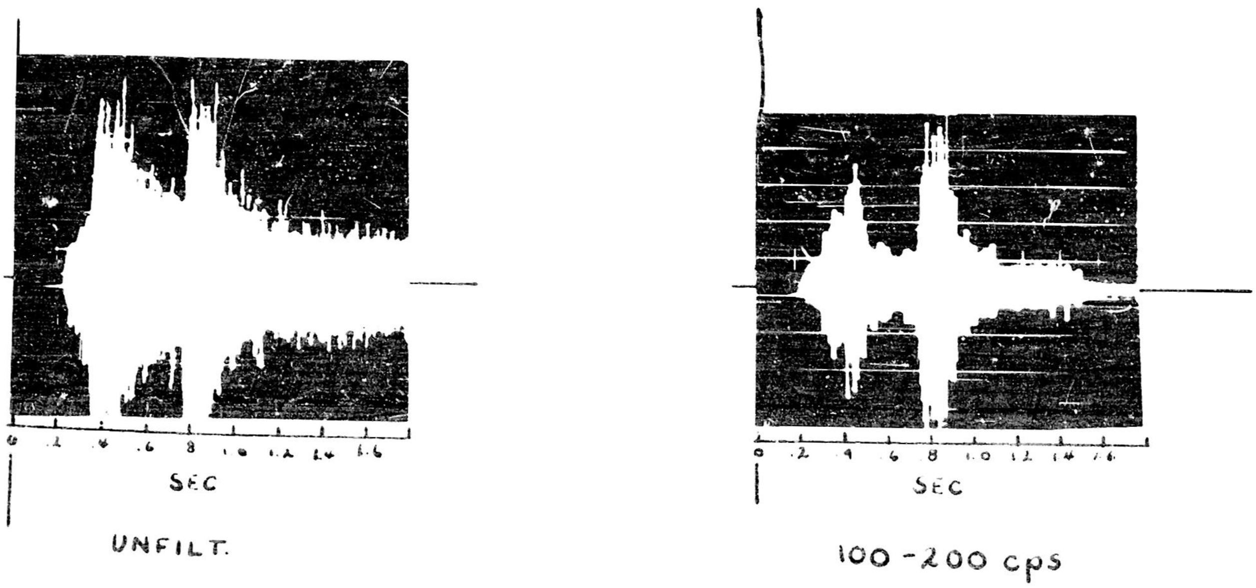


Mk. 36
(a)



Mk. 39
(b)

Fig. 1

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dated 28 April 1952 CONFIDENTIAL

b) Naval Ordnance Test Station, NOTS Technical Memorandum 660 "Water-Entry Noise Study of Air Launched Missiles"
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c) Woods Hole Oceanographic Institution, Reference No. 52-73, "A Reconnaissance Investigation of Acoustic Ambient Noise off Boston Harbor"
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d) Catholic University of America, Final Report on Contract Nonr-894-00, "Model Experiments on the Acoustic Signal from Airdropped Mines"
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e) Underwater Explosions, by R. H. Cole, Princeton University Press,
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f) Columbia University, Project MICHAEL, Technical Report No. 7, "Transmission Tests at USNEF, Eleuthera Part II"
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g) H. M. Underwater Detection Establishment, Portland, Scientific and Technical Progress Report 1952/1.(ACSIL/ADM/52/399)
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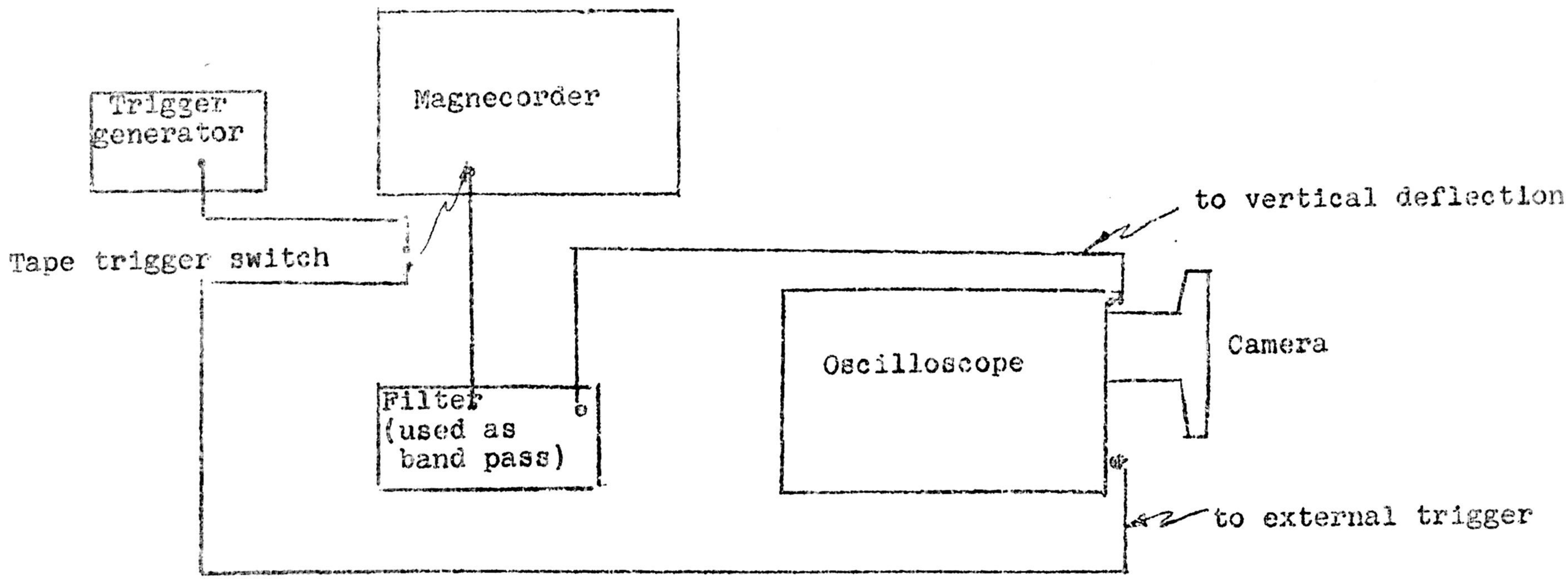

Figure #2

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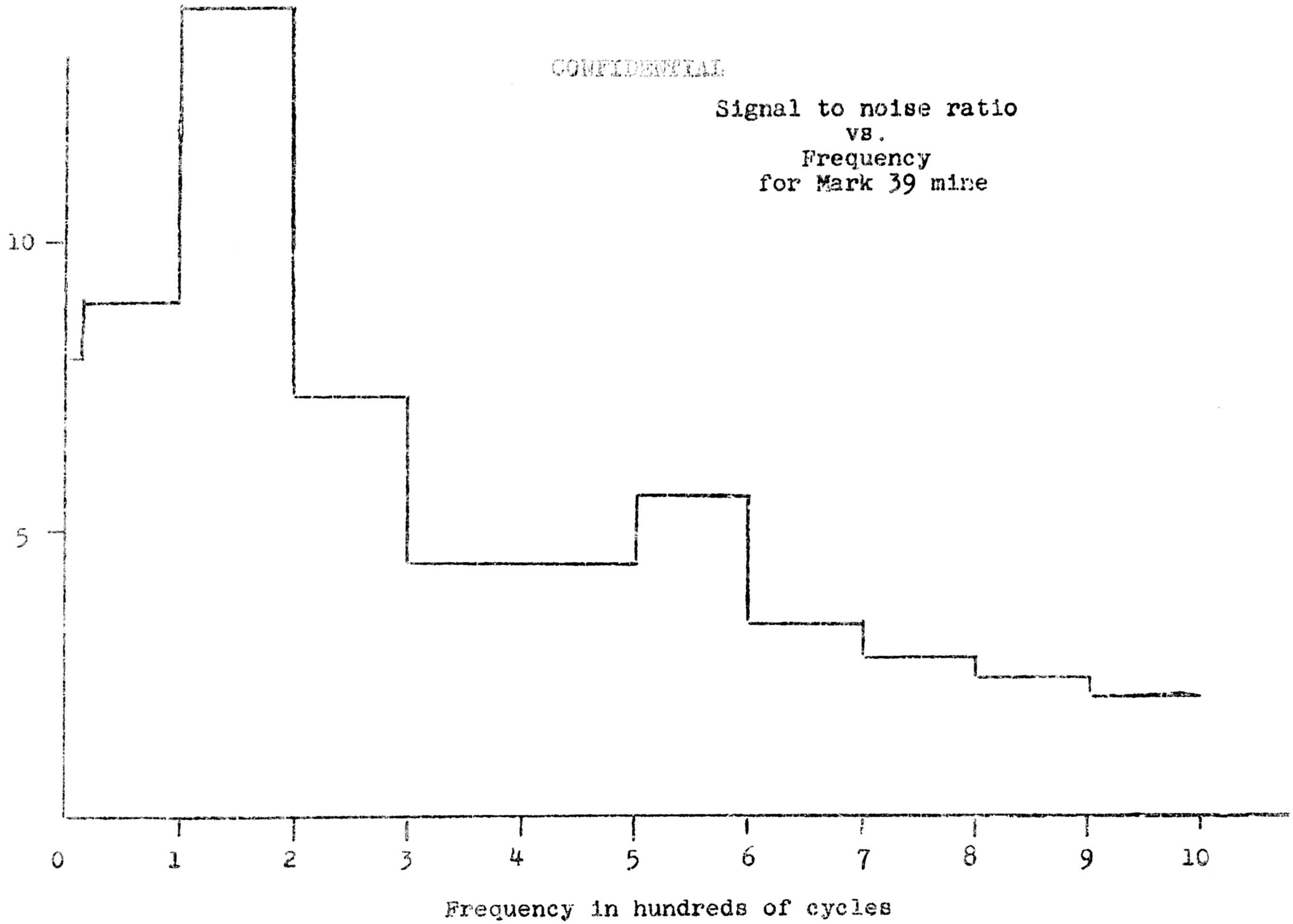

Graph #1

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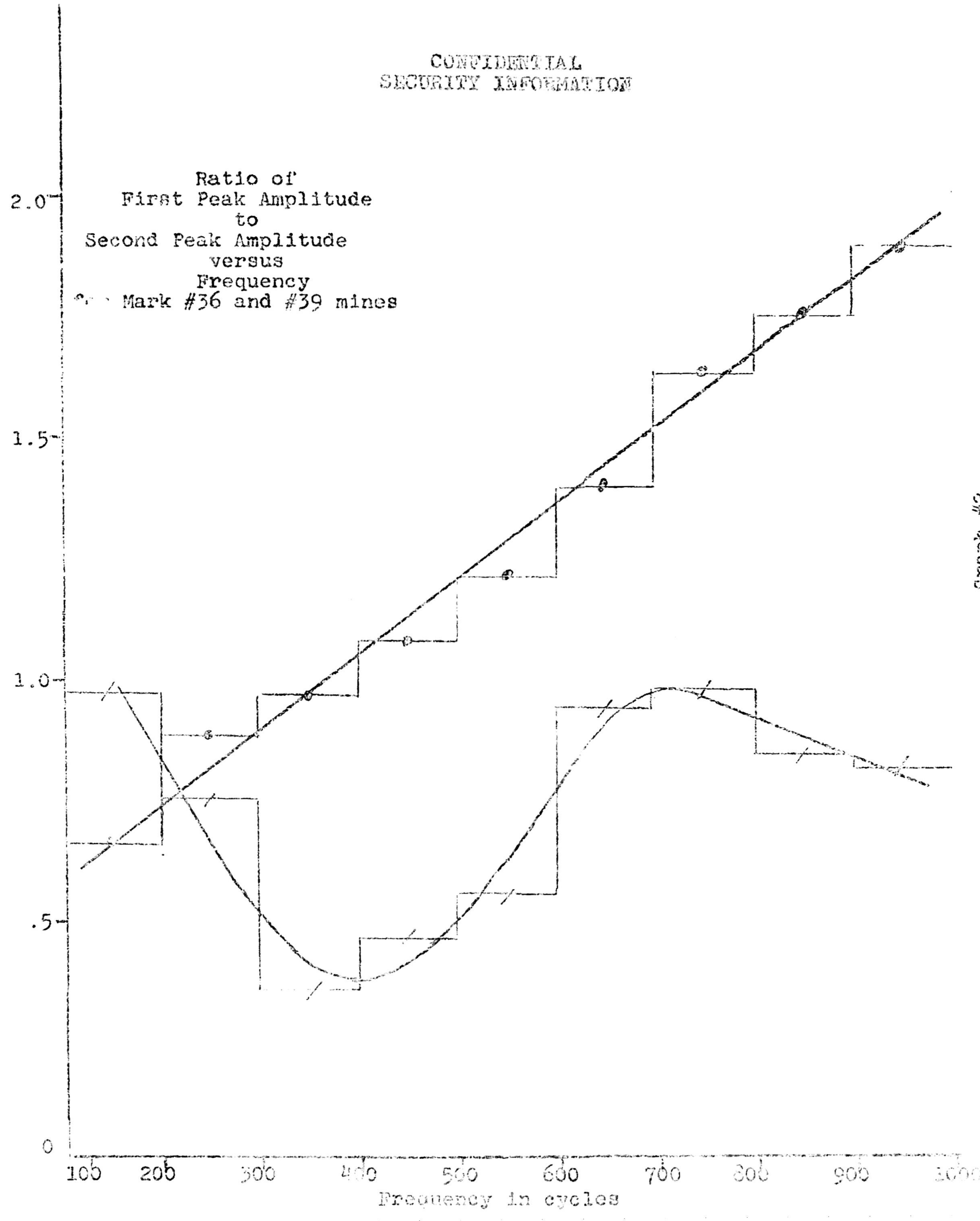

Graph #2